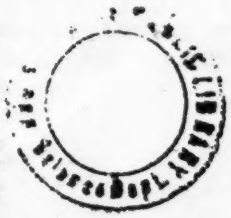
8



TRANSACTIONS

OF THE

ILLUMINATING ENGINEERING SOCIETY

FOUNDED IN LONDON 1909 INCORPORATED 1930

CONTENTS

	Page
Notes on Recent Meetings and Events	51
Annual General Meeting	51
Diffusion and Shadows By Howard Long, A.M.I.E.E.	52

VOLUME II—No. 4
APRIL, 1937

32 VICTORIA STREET
LONDON SW1

NOTES ON RECENT MEETINGS AND EVENTS

General Meeting in London.

A meeting of the Society was held in the Lecture Theatre of the Institution of Mechanical Engineers, Westminster, S.W.1, on Tuesday, March 9. The chair was taken by the President at 7 p.m.

The minutes of the last meeting having been taken as read, the names of applicants for membership were presented in the usual way.

The President then called upon Dr. S. English and Mr. R. Maxted to present their papers entitled, "Some Aspects of the Street Lighting Problem" and "The Representation of Lantern Characteristics." On the motion of the President, a cordial vote of thanks was passed to Dr. English and Mr. Maxted for their interesting papers.

An interesting discussion followed, in which, amongst others, the following took part:—Mr. C. C. Paterson, Mr. E. J. Stewart, Mr. J. S. Preston, Mr. J. M. Waldram, Mr. F. C. Smith, Mr. J. S. Dow, Mr. C. A. Morton, Mr. A. R. McGibbon, Mr. R. G. Hopkinson, and Mr. Percy Good.

Dr. English and Mr. Maxted briefly replied to the discussion, and the meeting then terminated.

Sectional Meetings.

The second meeting of the Industrial Lighting Section was held, by invitation of the General Electric Co., Ltd., at Magnet House, London, on March 24. Mr. R. O. Ackerley presided.

Short contributions dealing with special problems in industrial lighting were presented by Mr. T. C. Angus, Mr. E. L. Calvert, Mr. J. B. Carne, Mr. W. Imrie-Smith, Mr. J. E. Lane, and Mr. L. M. Tye, and were discussed with much interest by those present.

A vote of thanks was accorded to the authors, and to the General Electric Co., Ltd. for their hospitality during a most successful evening.

Members of the Section on Photometry, and friends, visited and inspected the research laboratories of Messrs. Kodak Ltd., on April 6, when an address was given by Mr. E. W. Selwyn on "Photographic Photometry." Visitors were also given a striking demonstration of films and lantern slides taken in natural colours by a new process. Mr. H. Buckley expressed the thanks of the party to Messrs. Kodak Ltd., for this very instructive and entertaining visit.

Applications for Membership.

At the general meeting of the Society, held on March 9, the names of the following applicants for membership were presented:—

Elections Pending.

CORPORATE MEMBERS:—

Campbell, J. H. .....40, Sunlight House, Quay Street, MANCHESTER.

Dew, H. G. .....Midacre, Love Lane, Woodford Bridge, ESSEX.

Hawkins, A. G. .....15, Delaheys Road, Hale, CHESHIRE.

Machin, C. F. .....64, Draycott Avenue, Kenton, Harrow, MIDDLESEX.

Oaks, P. R. G. .....Breandown, 22, Holders Hill Drive, HENDON, N.W.4.

COUNTRY MEMBERS:—

Ritchie, A. .....120, George Street, GLASGOW.

Ward, G. A. .....Cleveland Public Library, 325, Superior Avenue, Cleveland, OHIO, U.S.A.

Elections Completed.

At this meeting the names of those announced on February 23, which were published in the issue of the *Transactions* (Vol. II., No. 3, p. 34, March, 1937), were read again, and these applicants were formally declared members of the Society.

ANNUAL GENERAL MEETING

The annual general meeting will be held in the Lecture Theatre of the Institution of Mechanical Engineers, Westminster, S.W.1, at 7 p.m., on Wednesday, May 19, when the annual report of the Council and the accounts for the past year will be presented for adoption and auditors for the coming session will be elected.

At the conclusion of formal business a series of brief addresses will be given dealing with the Coronation lighting.

DIFFUSION AND SHADOWS

by HOWARD LONG, A.M.I.E.E.
(Member).

(Paper read on Tuesday, February 23rd, 1937.)

Introduction.

This paper was prepared at the request of the Technical Committee of the Illuminating Engineering Society. The author, as a member of the sub-committee of the British National Illumination Committee concerned with this subject, has aimed at furnishing a record of the work done and an indication of the problems yet to be solved. It is hoped that the brevity of the paper will be counterbalanced by a very valuable discussion, which will provide the sub-committee with useful information on which to work.

At the International Commission on Illumination meeting at Cambridge in 1931 "Shadows" formed one of the new subjects set down for study with Germany as the secretariat, the terms of reference being: "Evaluation of shadows from the point of view of efficiency and comfort. Practical methods." A sub-committee was formed in this country in December, 1933. At an early meeting the name of the sub-committee was changed to that of "Sub-committee on directional component in lighting."

Much work had previously been done in the subject, particularly by Norden (A) in Germany, whose researches extend over many years. In that country rules for shadow measurement exist.

Diffusion and Shadows.

Before proceeding with a more detailed study of the subject, it would be well to examine the practical application. It would be a fair statement of the case to say that, for general lighting, in most instances the illuminating engineer strives to minimise shadows. Yet there are visual tasks for which a directional light, producing shadows, is already regarded as necessary.

The subject may, therefore, be divided under these two main heads:—

(1) Where the maximum diffusion is the objective.

(2) Where the provision of shadows is the main requirement.

Diffusion.

Despite the long period during which the attainment of "maximum diffusion" has been regarded as a goal and the widespread use of this term, no proper method of measurement has been proposed. Although there is a British Standard definition for Uniformity —a very close partner of Diffusion—there is no definition of the latter.

It was proposed by the British Committee at the I.C.I., Germany, 1935, that the degree of diffusion of an installation should be given by the expression:—

$$D = \frac{E_l}{E} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where E_l = the illumination in the worst shadow.

E = the illumination without the shadow.

This, however, was not carried, as the German Committee, who have done so much work in this field, found the proposal would clash with the rules for shadow measurement existing in their country.

Shadow Factor.

In Germany the shadow factor (s) or "shadiness" is given by the ratio:—

$$S = \frac{E_s}{E} \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

where E_s = the direct illumination from the fitting which will be shaded out by the shadow-forming obstruction = $E - E_l$.

E = the illumination without the shadow.

Expression (1) has the advantage of simplicity in that it is obtained directly from the two readings and gives (when multiplied by 100) 100 per cent. diffusion when $E_l = E$, i.e., when no shadow is measurable, which is logical and the most useful method when diffusion is the objective. On the other hand, there is so much work to be done on the subject that it is wise to accept the I.C.I. decision and use expression (2). This gives (when multiplied by 100) a figure of 100 per cent. when the illumination in the

shadow is zero, i.e., $E_i = o$, and is the logical expression when the provision of shadow is the desideratum.

Cases for the Avoidance of Shadow.

Continuing with consideration of the practical value of this study, two main cases for the avoidance of shadow can be set down:—

(a) Where work is done on plane surfaces, such as in clerical offices and drawing offices.

(b) As indicated by Lythgoe (B), it is desirable for the greatest seeing power that the brightness of the visual task should be slightly greater than that of the surroundings in the field of view. If a shadow is cast on the work so that the brightness of the surrounding field is the greater then the seeing power is reduced to that with a lower value of illumination without the shadow, i.e., a shadowed illumination is less effective than a uniformly bright illumination equal to the shadowed illumination. Norden terms this "Contrast Induction."

The Value of Shadow.

Shadows of value are "Revealing Shadows." Those commonly known reveal the form of solid objects without which a uniform tone solid appears as a plane surface. The paper of Arndt (C) deals more fully with this aspect of the subject, which is not the main interest at present. With 100 per cent. Diffusion—which can only be obtained in an enclosure having the properties of an integrating sphere photometer—no shadows are possible and there is then a complete lack of form, provided the solid is of the same colour tone all over.

In addition there are "Revealing Shadows" which enable seeing, even with substantially plane surfaces. Many instances of this exist, but as examples one may quote "Braille" sheets and textiles. It is well known that in these cases a large direct (and oblique) component of illumination is useful. But this will be dealt with more fully later on.

Having now some little idea of what is a shadow and what is the value of this work, one may proceed with a more detailed study of the subject.

Attainment of Diffusion.

It is apparent that the provision of Diffusion by general lighting enters into almost every installation. Consideration of this aspect of the subject is, therefore, of much more widespread value than the provision of shadows which, in most cases, can be considered only as supplementary to the general lighting.

The work of the British Committee (individually and collectively) has resulted in a clear understanding of the factors which control Diffusion from a general lighting system. Illuminating engineers with wide experience of general lighting systems have derived some inkling of these factors from practical experience, but this would appear to be the first systematic study on a scientific basis.

Several practical tests of typical installations led the committee to the decision that:—

(a) *The spacing of the reflectors has the greatest effect on the Diffusion.*

The installations studied which led to this conclusion employed prismatic glass, vitreous enamelled and mirrored glass reflectors. These installations included those giving the same average illumination with reflectors at the same height, but with various spacings (correct for their spacing-height ratio), and therefore different lamp sizes. For confirmation, systems of reflectors with different distributions, but the same spacing, height and lamp size were considered.

A contribution by Buckley arising out of previous work on Uniformity (D), which has a bearing on Diffusion, showed from a mathematical study that:

Other factors being equal:

(b) *Only when the classes of light distribution vary widely does the distribution have any appreciable effect on Diffusion.*

(c) *The wider the distribution the greater the Diffusion.*

(d) *The closer the spacing (with greater uniformity) the less the effect of light distribution.*

These new facts may well upset the previous notions of spacing-height ratios.

The Shadow Caster.

To enable any progress to be made it was obviously necessary to establish a method of measurement. As a rough guide to the diffusion obtained, the author has for several years measured the illumination (E_i) in the worst shadow cast on the work by any worker A further measurement of the unobstructed illumination E then enables the ratio $\frac{E_i}{E}$ to be determined. This method is useless, of course, for a more detailed study of the subject, as the human body is not a reproducible standard, and the light from a varying number of fittings is obstructed.

Several forms of shadow caster have been evolved, but none is yet standardised. This is the most pressing work for the I.C.I. in connection with shadows.

The shadow caster designed by Norden consists of a circular opaque disc about 13/16 in. diameter arranged about 1¾ inches above the comparison surface of a visual type portable photometer or above a photo-voltaic cell. The disc is movably attached to a wire bent in the form of a semi-circle and pivoted at the diameter of the curve. Thus the disc may be adjusted to any position of zenith and nadir. To facilitate adjustment a small lens is provided in the centre of the disc, whereby an image of the source to be shaded off is produced on the centre of the

measuring area. The lens is covered by a lid when the measurement is being taken.

Shadows.

To determine the Shadow factor $\frac{E_s}{E}$ it is necessary to take two measurements, namely, E_i (in the shadow) and E (without the shadow), but instead of employing the direct ratio of these readings, E_s (the illumination from the fitting shaded out) has to be found from the expression:—

$$E_s = E - E_i \quad \ldots\ldots\ldots\ldots (3).$$

A very valuable analysis of the illumination at any point is possible by determining the shadow factor for each source contributing at that point. Thus, the direct and diffused components and the direction of the principal shadow (if any) are found.

By such analysis it is possible to allocate the cause of any depreciation of illumination due to walls and ceiling and the amount due to the sources.

Processes Where Directional Component (i.e. Some Degree of Shadow) is Essential.

The British Committee has so far listed the following processes. Additions will be made from time to time and any suggestions will be welcomed:—

Inspection of cigarettes for filling.
Production of Braille books.
"Make ready" for printing.
Marking and inspection of steel rules.
Laundries—classifying materials of garments.
Handling type—typesetting, mono-casting.
File cutting.
Engraving.
Inspection of glass, polished metal and tinplate (in this class extended sources are used).
In all cases where it is desired to see irregularities.
In virtually homogeneous surfaces of uniform colour.
Certain textile processes.
Leather grading.
Inspection of razor blades.
Inspection of fur.

To this list hand sewing can now be added.

Physiological Side of Shadow Engineering (E).

In a recent paper (F) under the above title Norden has presented a novel method for appraisal of an installation in accordance with the recommended value of illumination. This is too lengthy and involved to be explained in detail here but some extracts follow.

The law that defines "Contrast Induction" is stated to be:

$$C = k' (B_u - B_i) \quad \ldots\ldots\ldots (4).$$

where B_u is the brightness of the surroundings,
B_i is the brightness of the inner shadowed field,
k' is a coefficient determined as between 0.2 and 0.25 according to conditions.

Substituting illumination values E and E_i and writing $(E - E_s)$ for E_i from (2) $S = \frac{E - E_i}{S}$ equation (3) becomes

$$C' = k' E S \quad \ldots\ldots\ldots\ldots (5).$$

In the present state of knowledge this is an approximation.

The "Physiological Value" of the illumination (E_{ph}) in a shadow is found by deducting the "Contrast Value" C' from the illumination in the shadow E_i. Thus:

$$E_{ph} = (E_i - C') \text{ or substituting}$$
$$E_{ph} = E(1\text{-}s) - k'ES \quad \ldots\ldots\ldots (6).$$

The "Colour Variation" (in terms of the tintless scale) due to shadow is well known. A piece of white paper with a shadow cast on it appears darker in the shadow. Codes of recommended illumination values give higher values for dark goods, and this effect frequently means that light goods with a shadow must be considered as dark.

The accompanying table takes into account all the foregoing factors:—

As an example of the application of this method and an explanation of the foregoing table, take the case of a process for which the recommended value of illumination is 15 foot-candles and the diffusion from the scheme 80 per cent. We find that 20 foot-candles general illumination E must be provided to produce 15 foot-candles E_{ph}. Also it is seen that

Summary of Factors involved in Physiological Side of Shadow Engineering.

E	D=80%. R=48%.			D=60%. R=60%.			D=50%. R=67%.			D=40%. R=77%.			D=20%. R=*.		
ft.-c.	E_i	C'	E_{ph}	E_i	C'	E_{ph}	E_i	C'	E_{ph}	E_i	C'	E_{ph}	E_i	C'	E_{ph}
20	16	0.8—1	15	12	1.6—2	10	10	2—2.5	8	8	2.4—3	5.3	4	3.2—4	0.8
15	12	0.6—0.75	11.3	9	1.2—1.5	7.5	7.5	1.5—1.87	6	6	1.8—2.25	4	3	2.4—3	0.6
etc.	etc. E_{ph}: E=0.75.			etc. E_{ph}: E=0.5.			etc. E_{ph}: E=0.4.			etc. E_{ph}: E=0.26.			etc. E_{ph}: E=0.04.		

=reflection factor below which goods may be considered dark. *All goods may be considered as dark.

all materials having a lower reflection factor than 48 per cent. will come within the dark classification in the shadow (although without the shadow the borderline between light and dark is 40 per cent.). Therefore, goods with a lower reflection factor must be provided with a higher value of illumination than 20 foot-candles.

This is yet arbitrary. There will emerge a sliding scale of E values recommended for equivalent scale of reflection factors of goods, Diffusion values, etc.

It is hoped that sufficient has been said to give a practical picture of the subject and promote a useful discussion.

References.

(A) Basic Principles of Shadow Technique.—Dr. K. Norden.

(B) Visual Perceptions under Modern Conditions. Trans., Illum. Eng. Soc. (London), January, 1936.—Dr. R. J. Lythgoe.

(C) Über den Stand der Arbeiten Beleuchtung Räumlich zu Bewerten. Proc. Int. Illum. Congress, 1931.—Dr. W. Arndt.

(D) The Classification of Symmetrical Light Distributions. Illum. Eng. Soc. (London), June, 1936.—H. Buckley.

(E) Fundamentals of Shadow Engineering (Grundlagen der Schattentechnik. Union Deutsche Verlag.).—Dr. K. Norden.

(F) The Physiological Side of Shadow Engineering. Amer. I.E.S. Convention, 1936.—Dr. K. Norden.

DISCUSSION

Dr. K. NORDEN, giving a brief outline of some work he has recently done towards determining diffusion, said he had also had the idea of taking the "residual illumination in the worst shadow" as a criterion of the degree of diffusion, but had come to the conclusion that this was too rough a method. As the author had pointed out, the determination of diffusion involved the problem of defining diffusion and the problem of measuring it. There was a very conclusive definition, viz., "the diffusion of an illumination is defined by an incidence of light flux, which is all-directional and uniformly distributed," but, unfortunately, this covered only absolute or perfect diffusion of 100 per cent. degree, which was approximately realised in outdoor lighting by daylight from a moderately overcast sky but never in interior lighting. In order, therefore, to include all degrees of diffusion, the definition quoted needed to be slightly modified, viz., "the degree of diffusion of an illumination is defined by the extension of the luminous surface of the lighting unit and by the distribution of luminosity over this surface." This definition simplified the problem by reducing it to the more tangible one of determining the degrees of diffusion produced by extended luminous surfaces. From this basis it was possible to tackle the problem of measuring diffusion. It would be solved if a measurable quantity inherent to all extended light sources could be found which reacted on changes of surface extension and of luminosity distribution in analogy with our conception of diffusion. Such a quantity he had found to be the mean illumination in the semi-shadow or penumbra.

To understand this, it was necessary to remember the two principles underlying the analysis of an illumination by means of a properly dimensioned shadow caster, viz.: (1) the intensity of the intercepted or "shadowed" illumination indicates the directed part of the total illumination; and (2) the intensity of the residual illumination in the shadow, which is the illumination deprived of its directed or shadowy elements, indicates the diffused part of the total illumination.

Correspondingly, if the shadow caster was applied to the illumination from an extended light source, such illumination was purified of its shadowy ingredients, so that the diffusion contained therein was set free and its degree indicated by the mean illumination in the resultant semi-shadow, which, as could be demonstrated, behaved like diffusion towards the extension of the luminous surface and the distribution of its luminosity.

Having thus given a brief explanation of the underlying idea, Dr. Norden said the practical diffusion meter consists of the combination of a photoelectric meter with a specially designed shadow caster. One model was now under construction by a Berlin firm. Patents had been applied for, but licences would be granted on suitable terms to all manufacturers of photoelectric meters in order that the device might be as widely applied as possible.

To determine the diffused portion or "diffusion-factor" of an illumination from a single source, it was necessary to make two measurements: one with the shadow caster, which gave the residual-illumination E_r, and one without the shadow caster, which gave the unshaded illumination E, the result being $D_1 = \frac{E_r}{E}$. If a number of n light sources were used all components must be subject to the measurement with shadow caster one after the other, and combined with the full value E, according to the following formula:

$$\text{Total diffusion-factor } D_n = \frac{\sum_1^n E_r - E\,(n-1)}{E}$$

Furthermore, if single measurements were taken with different types of light sources or fittings in a test room of standardised size and paint, they would serve for numerically characterising the light-diffusing qualities of each type. Hitherto, such characterisation had only been possible vaguely by more or

less general description, but it could now be given accurately.

Dr. Norden said he was convinced that this method would also prove useful in confirming by measurement the most interesting facts regarding distribution and spacing which had been brought out by the splendid work of the British Committee, and for which he expressed his highest appreciation.

Mr. E. W. MURRAY, referring to the list of processes given in the paper for which it has been suggested by the British Committee some degree of shadow is necessary, said that he was not at all sure that such processes as marking and inspection of steel rules, engraving, inspection of glass, polished metal, and tin plate, require shadow. He was of the opinion that these were the cases which require an illuminant of large area but of low brightness. Further, there are a number of other processes which should be included, such as fustian cutting, goffering, pleating, in dressmaking and laundering, carving, drilling, etc. He demonstrated the advantage of shadow for some of these processes.

Lieut.-Col. KENELM EDGCUMBE remarked that from the formulae given by Dr. Norden it seemed that he really agreed with the proposal of the British Committee. Dr. Norden had used E_r whereas the British Committee used E_i, but they appeared to mean the same thing, viz. the residue of light in the shadow.

He suggested that E_s (i.e. $E—E_i$) could be measured direct by shading off all the light other than that coming from the fitting under investigation. This would overcome the objection that a small quantity was being measured by taking the difference of two relatively large quantities. A tube with diaphragm at each end, held over the photoelectric cell, would enable this to be done without difficulty.

He asked the author for some information as to the dimensions and method of using the Norden shadow caster. In the only description he had seen of the instrument it had what seemed to him quite arbitrary dimensions, namely 20.8 mm. in diameter, held 43 mm. from the surface. He asked how these dimensions were arrived at, and said he assumed they were empirical and that there was no theoretical reason why they should be the best dimensions.

Dr. NORDEN, replying to Colonel Edgcumbe with regard to the difference between the British proposal and his own formula, said he understood the idea of the British Committee was to characterise the diffusion of an installation with any number of light sources by the diffusion in the worst, i.e., most intense shadow. In contradistinction hereto his formula $D = \frac{E_r}{E}$ referred to an installation with only one single light source, but did not apply to the case of several light sources, which was covered by the more complicated formula of D_n taking also account of the less intense shadows.

With regard to the shadow caster being held horizontally he said that if they wanted to determine the diffusion prevailing at a certain place, it was necessary to shade off the directional light sources from this place by focusing the caster to each of them; that was the reason why the shadow caster had to be movable and not limited to the horizontal position where no light source might be met at all. In other words: in order to measure the diffusion of the total illumination they had to take one component after the other at whatever angle it might be found and to eliminate all directional portions.

Coming to the question of the dimensions of the shadow caster, he said it must be so dimensioned that the directed part of the illumination was intercepted by it, and absolutely no more. That was the reason for the small dimensions of his older caster which had been mentioned by the author—much smaller indeed than those of the tester employed to-night in the author's test. But even these small dimensions of his caster were still too wide, as this caster was designed for use in conjunction with the optical illuminometer. This type of instrument, moreover, required uniformity of the shadow to be measured, otherwise it was impossible to make photometric comparisons of the adjacent fields; therefore it had been necessary to compromise and make the disc so wide that in the majority of cases it would give a uniform shadow. When using the photoelectric illuminometer which integrated the light flux from point to point across the surface, thus indicating the mean illumination value, they were free from that difficulty, so that in his latest model of the shadow caster the angle subtended by the disc could be reduced to about 4° against 11°, and the accuracy of the instrument increased accordingly.

Dr. J. W. T. WALSH expressed the view that the subject of shadows and diffusion was not receiving the attention it should have, and he valued the paper the more highly on that account. He looked forward to the time when there would be definite prescriptions as regards shadow and diffusion in illumination, and hoped this would not be the last paper they would have on this very important subject. There was a great need for standardisation or international agreement at an early stage with regard to the manner in which was expressed the degree of diffusion of a system of lighting—and he took it they were now dealing mainly with systems of lighting. He therefore hoped there would be some such agreement. At the same time, he thought the British method of defining diffusion, i.e., as a direct ratio of the two quantities measured, had several practical advantages. For one thing, it avoided the uncertainty introduced when a (possibly) small quantity was found as the difference between two larger quantities. He had to confess that he had been completely defeated by the last section of the paper dealing with the physiological value of illumination. He had tried to apply the author's table in the case of an installation for, say, reading purposes, and, taking the modest value of 5 foot-candles as the requirement for the ordinary reading of black print

on white paper, if the diffusion coefficient of the installation was 20 per cent., the ratio of $\frac{E_{ph}}{E}$ was 0.04, according to the table. This seemed to give an actual E of 125 foot-candles, and he could not believe it. Perhaps the author would say where he had gone adrift in this matter.

Reference had been made by Dr. Norden to the use of the photoelectric cell and, presumably, he meant the type which was known over here as the rectifier or plate type. However, he could see some pitfalls if this device were used without a good deal of caution. It was well known that these cells departed markedly from a true indication when the light was incident at fairly steep angles, and, further, the sensitivity was not uniform over the whole of plate, but increased towards the edge. Both these complications would have to be taken into account when using photoelectric cells in a shadow caster.

Mr. J. M. WALDRAM congratulated the author on dealing with a subject which he felt lay at the very heart of illuminating engineering; in fact, he doubted whether illuminating engineers could be properly so called unless they dealt with this side of their problem. In such subjects there was a tendency on the one hand to specify as soon as possible; on the other hand, to run unnecessarily to mathematical extremes. He was inclined to question the desirability of establishing empirical methods of shadow measurement, which amounted to defining shadow, before the desirable qualities of light and shade for various visual purposes were better established. There was sometimes a tendency to go to the extreme of regarding absolute uniformity and complete diffusion as a desideratum, just as there was a tendency to make things straight or circular or flat, for no reason except the ease with which they could be so drawn or made. An absolutely uniform illumination was most depressing. It was probably true that the extremes of completely directional or completely diffused light were very seldom required, but that nearly all visual tasks required some carefully prescribed mixture of the two.

He pointed out the difficulty which sometimes attended the adoption of formulae to define such a quantity as shadiness. It was quite possible to use a formula which was mathematically quite a legitimate function of the quantities concerned, but which resulted in numbers which bore no relation whatever to the impression received by the eye. This was true of some expressions used to express contrast, for example. Had the author found that the numbers given by his formulae were in accord with the visual impressions?

He looked forward to further developments along the lines which the author had suggested, and to an understanding of vision based not so much upon the study of properties of the eye as on the study of the things seen, and the way in which, by the interplay of light and shade, reflections and colour, their form and details were best recognised.

Mr. J. S. Dow, commenting upon Mr. Waldram's remark that the estimation of shadows was an essential part of the work of the illuminating engineer, suggested that one might go further and say that the *physiological impression* made by the shadow should be considered. The impression produced by a shadow was mainly a matter of contrast, but it was possible that the appearance—for a given numerical contrast — might vary with the brightness. If the brightness of each of two adjacent surfaces were multiplied by 100 or 1,000, would the impression of contrast formed by the eye be the same? From his experience in examining photographs by different illuminations he thought there was a difference. At exceptionally high illuminations the contrast appeared much more vivid, though the same numerically. This seemed in some degree borne out by Mr. Ward Harrison's recent contribution to the "Transactions" of the American Illuminating Engineering Society, in which the interesting suggestion was made that an extreme—actually "glaring"—contrast became accentuated when the general scale of brightness was increased. In the case of very weak illuminations the reverse effect might be found, i.e., a given contrast might appear less evident—which, perhaps, afforded one explanation of the fact that quite considerable variations in brightness might occur in a street without being very noticeable provided the transition was gradual

Mr. W. J. RAFFÉ said that if the Society would arrange a section dealing with artistic aspects of lighting this would help considerably towards the study of these problems of shadow and diffusion. Personally, he was not qualified to go into the mathematical side because he had been trained as an artist.

As such he had found both direct and diffuse lighting useful. On the industrial side, however, from what he had seen of many factories, and particularly textile factories, it seemed to him that the processes were as much a problem for the fingers as for the eye. The same thing applied to pottery work in a large degree: a great deal was done by touch. Nevertheless, diffusion and shadow was extremely useful for distinguishing between different types of material. The whole problem of diffusion seemed to be akin to the study of the standard black body in relation to absorption. Mr. Raffé concluded by saying that a great deal would be learned in regard to these problems in artificial lighting by a study of diffusion under natural lighting conditions.

Mr. T. N. RILEY said that Dr. Norden had stated the conditions governing the size of the shadow caster only in very general terms, and asked if it were possible to state more definitely the relation between the diameter of the shadow-caster disc and that of the sensitive disc of the photometer; also their optimum distance apart for satisfactory operation.

Mr. H. LINGARD asked if the consideration of this problem had advanced sufficiently to enable some specification to be drawn up on the bases of a table giving illumination levels and uniformity ratios together with shadow factors. He also asked if the

method which had been described had been worked out for small rooms with one light source when comparing a clear lamp with a diffusing globe. Everyone with experience of illuminating engineering knew that when a change was made from a clear lamp to a diffusing globe under such conditions the shadows were softened considerably, and he asked whether the shadow caster had been applied to such a case.

The PRESIDENT, referring to Mr. Raffé's remarks, mentioned that the Council had under consideration the formation of a section dealing with Decorative Lighting, which would be able to handle the problems he had in mind.

In inviting Mr. Long to reply to the discussion, he drew attention to the impression that the British Committee were attempting to define the diffusion of an installation, whereas, with his shadow caster, Dr. Norden was apparently determining the shadow factor under a single fitting. This was an important distinction, which he hoped Mr. Long would make quite clear.

Mr. HOWARD LONG, replying to the discussion, dealt first with the point raised by Dr. Norden and others, as to why it was suggested that the diffusion should be measured in the position of worst shadow, and also why the demonstrations given during the reading of the paper had been in a particular position. Actually, an arbitrary position had been taken, but it is necessary to find the condition in the worst shadow in the working area in order to arrive at an evaluation of a particular system. It was emphasised that a complete installation was under consideration and not a particular fitting. The British Committee feel that the most valuable part of this work is in being able to determine and, if possible, predetermine the condition of diffusion over the working area. That is the first fundamental. The important thing was that there should be a general system of diffused lighting in practically all cases, and that any directional effect should be superimposed on that basic illumination. The point raised by Dr. Norden with regard to the size of the lighting units is only of importance when the lighting unit is of considerable dimensions. Normal lighting units are substantially of the same size; the variations are so small compared with the distance between the fittings that their actual size is relatively unimportant.

With regard to E_r, mentioned by Dr. Norden and others, Mr. Long remarked that the answer is fairly simple. In Dr. Norden's case, when dealing with E_r, he is dealing with the effect from individual fittings, whereas the British Committee, in taking E_l, is dealing with the total effect at any given point. Perhaps, however, we did not know all about that phase of the subject yet, otherwise the changing of symbols is to be deprecated. In the paper the symbols are those which have been used in the work already done on the subject.

Mr. LONG thanked Mr. Murray for his suggestions as to other processes where shadow was necessary, and said the Committee would be glad to receive others.

In reply to Col. Edgcumbe, he said he did not yet quite see how it was possible to shade out the remainder. No doubt Col. Edgcumbe had something in mind when he mentioned this, but personally he did not see, off-hand, how it could be done.

Commenting on Dr. Walsh's remarks on the physiological effect, he said the table in the paper showed how this worked out mathematically. The practical interpretation was that in all cases under these conditions the object being viewed must be regarded as being dark. It had been found that working on dark materials it was necessary to provide ten times the illumination required when working on light materials.

In regard to what Mr. Waldram had said with regard to the value of the measurement of diffusion, he had tried to explain in the paper that this was a practical appraisal of the degree of diffusion in a natural installation where work had to be done. He thanked Mr. Waldram for calling attention to the importance of superimposing directional effects on the general basic illumination. In the same way, the point suggested by Mr. Dow was of great importance, but he felt that it was one on which very little was known. Perhaps Dr. Norden was the best person to answer the question put by Mr. Riley concerning the shadow caster.

On the question of colour contrast mentioned by Mr. Raffé, the author referred to the paper read by Dr. Norden in America, where this question was considered in terms of "neutral colour." He personally saw no reason why the colour within a shadow should be different from the colour without the shadow, provided always that the illumination in the room from the various sources was the same colour. The question of feeling, also mentioned by Mr. Raffé, was rather outside the scope of the paper. His own view on that subject, which he thought was also the general view of illuminating engineers, was that in any event a man could do his work better and in greater comfort if it was correctly illuminated.

In reply to Mr. Lingard's question as to whether the Committee had advanced sufficiently to specify certain values of diffusion and shadow, the author said the Committee had explored clerical work and did not understand why the German Illuminating Society gave a figure limiting the amount of diffusion in this case. The British Committee thought

there was no limit to the diffusion that might be provided for clerical work. The German Committee gave a maximum of 80 per cent. diffusion or 0.2 per cent. shadow factor. The British Committee was not sufficiently advanced to do what Mr. Lingard had suggested. The object of reading this paper, however, was to assist to that end. Neither had a great deal been done with small rooms, also mentioned by Mr. Lingard, but it was perfectly obvious that if the decorations were not too light, the shadow caster would show an appreciable difference between the diffusion with a bare lamp and an enclosing globe.

A cordial vote of thanks was passed to Mr. Long at the conclusion of the discussion.

The Illuminating Engineering Society is not, as a body, responsible for the opinions expressed by individual authors or speakers.

With a view to avoiding possible confusion with other publications, reference to these Transactions should be in the form :—" Trans. Illum. Eng. Soc. (London)."

Printed by the ARGUS PRESS, LTD., Temple-avenue and Tudor-street, London, E.C.4, England.